

# Iron K band Observations of Active Galactic Nuclei

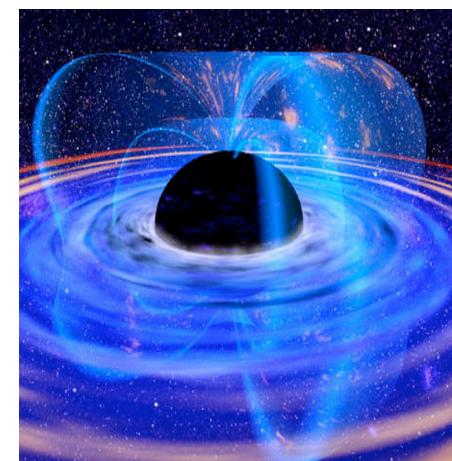
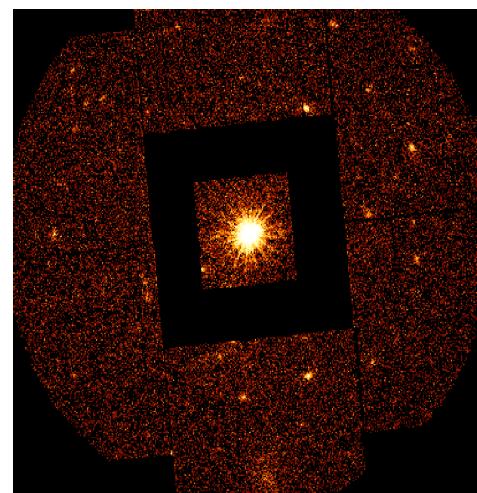
James Reeves

*NASA Goddard Space Flight  
Center*

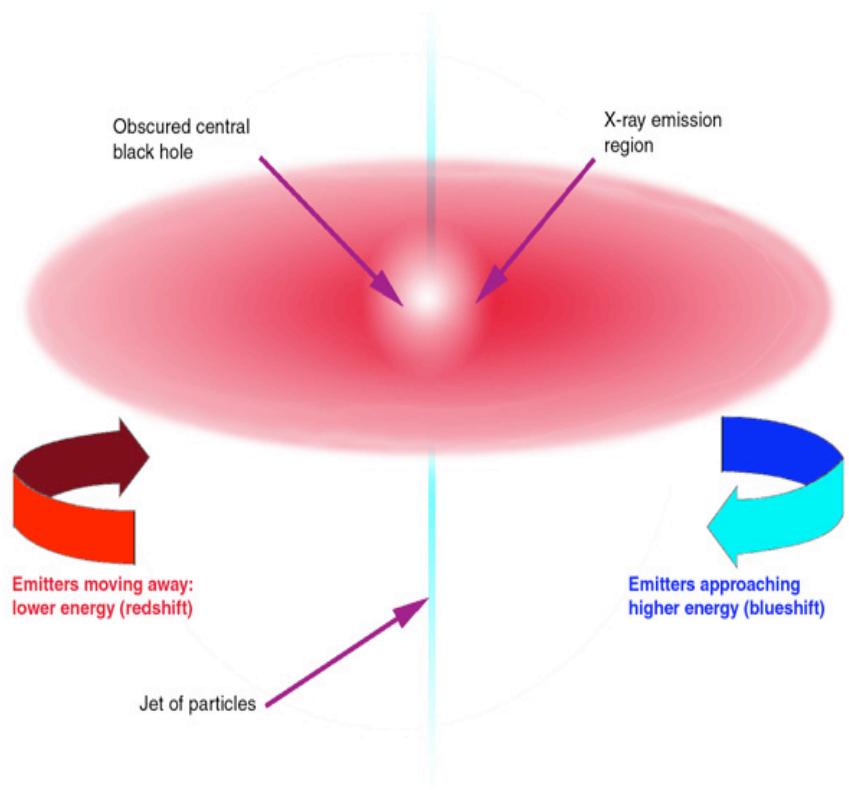
**Collaborators:-**

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Page, Martin Turner, Andrew  
King (Univ of Leicester)**

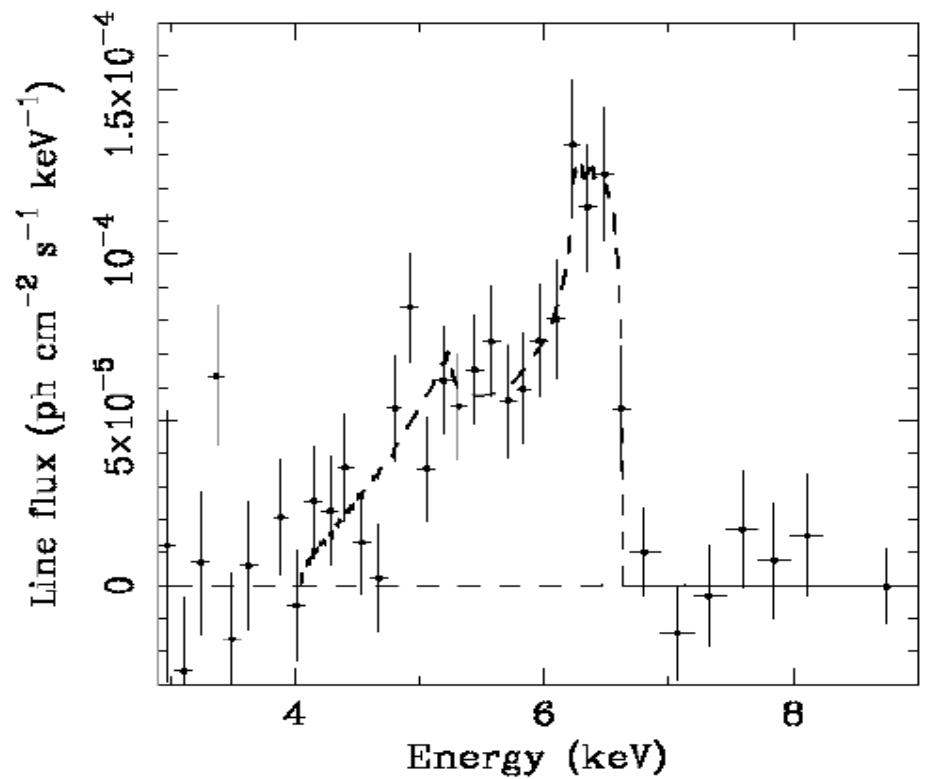
**Ian George, Richard Mushotzky,  
Jane Turner, Tahir Yaqoob  
(GSFC)**



# AGN accretion disc – the ‘broad’ Fe K $\alpha$ line



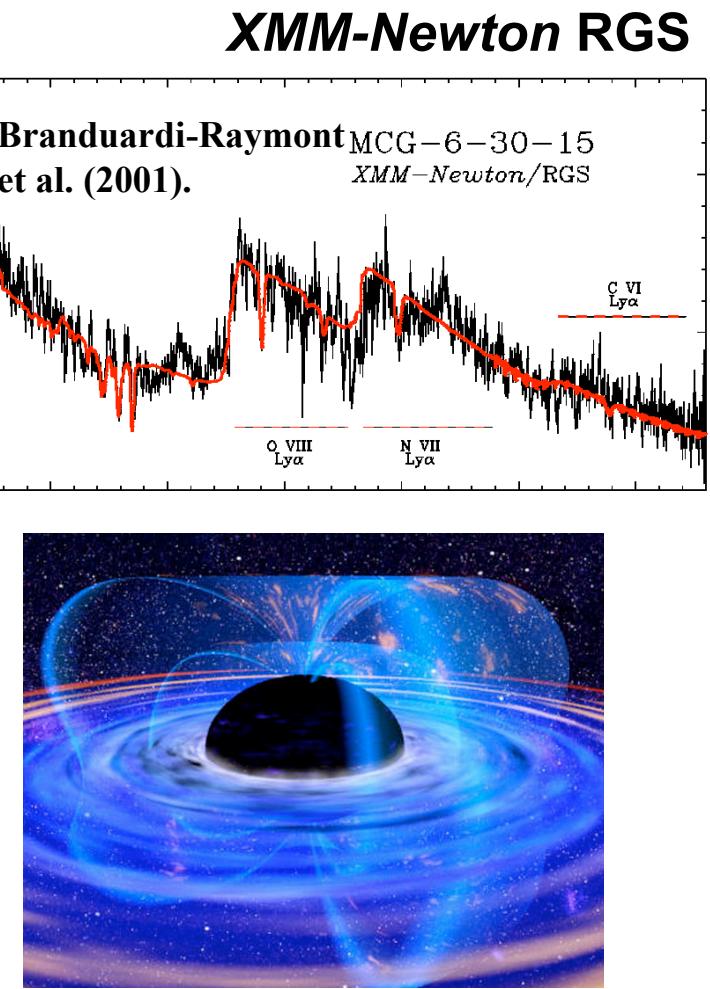
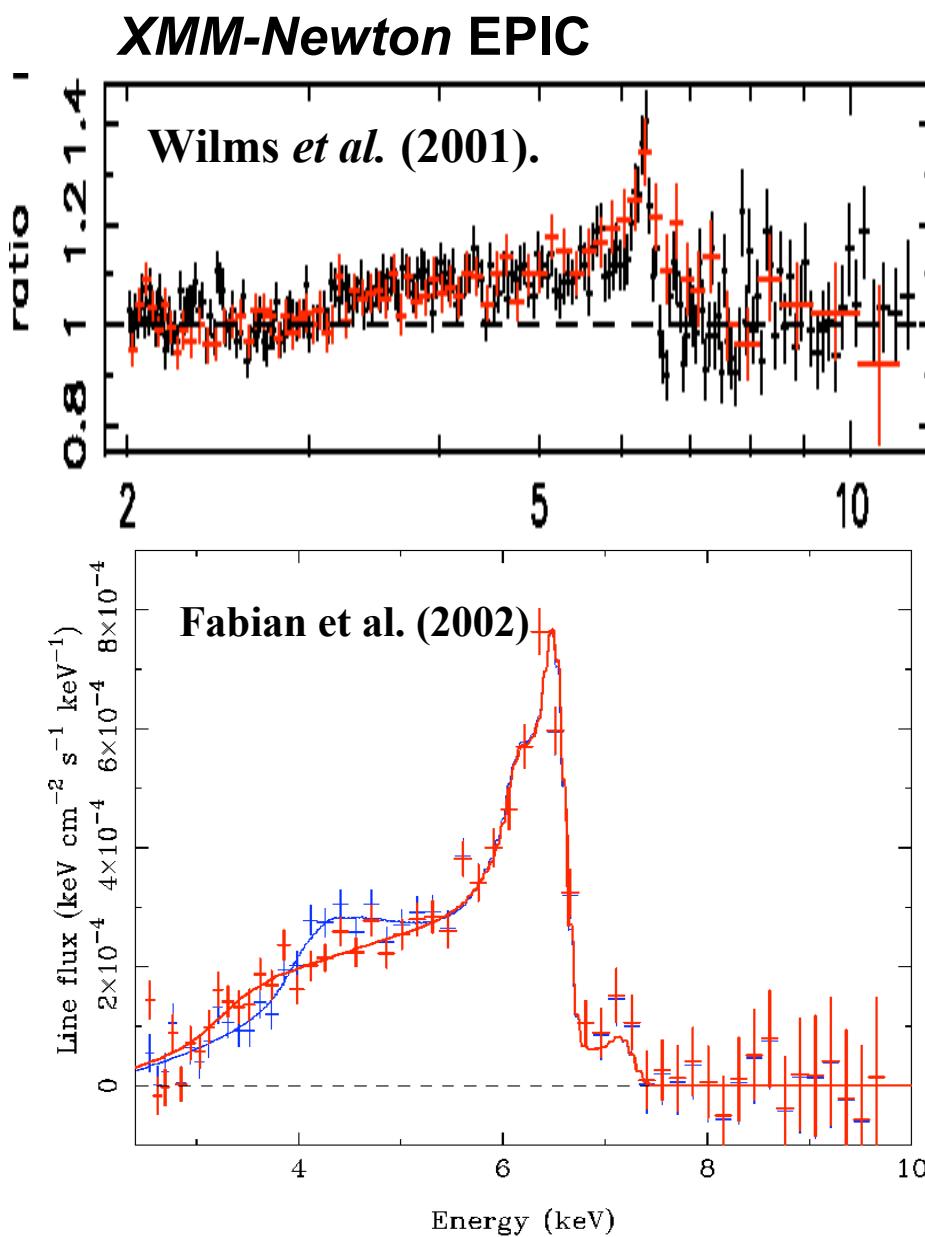
MCG-6-30-15: Tanaka *et al.* (1995)



. Hard X-rays illuminate ‘cold’ inner accretion disc

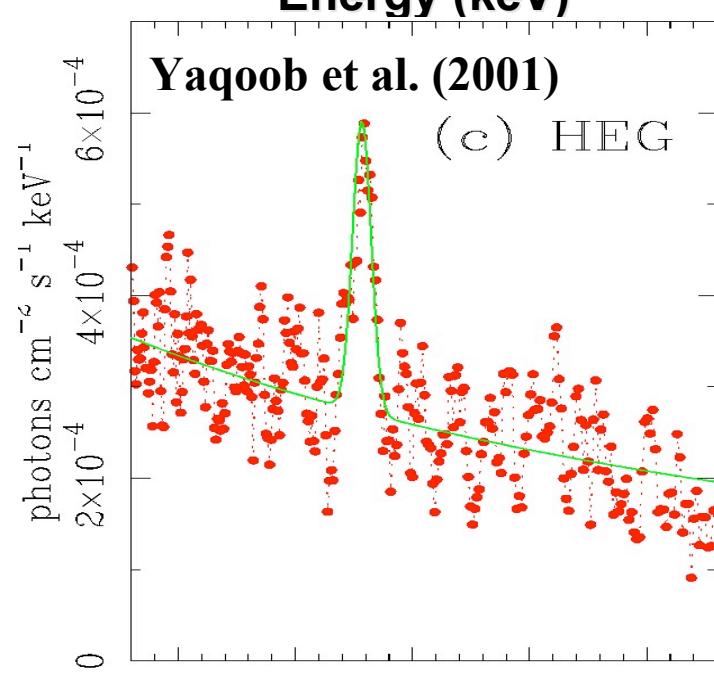
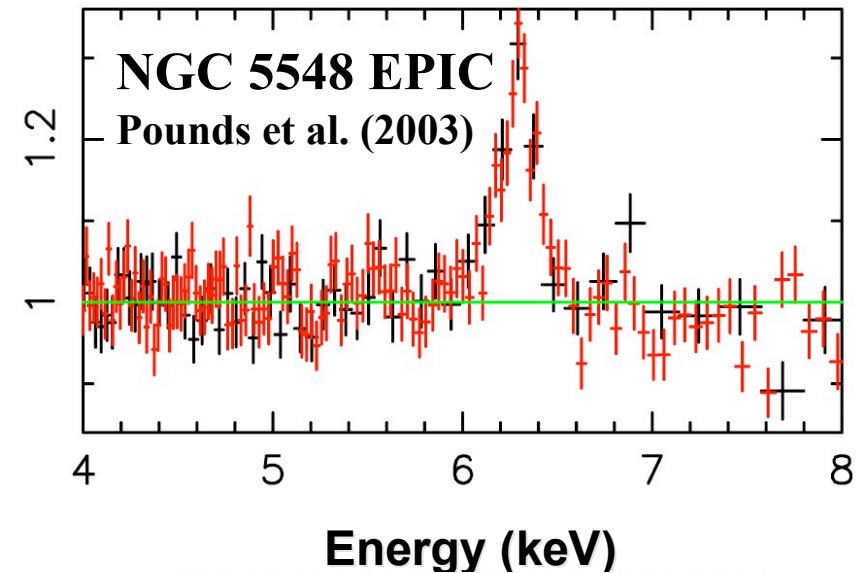
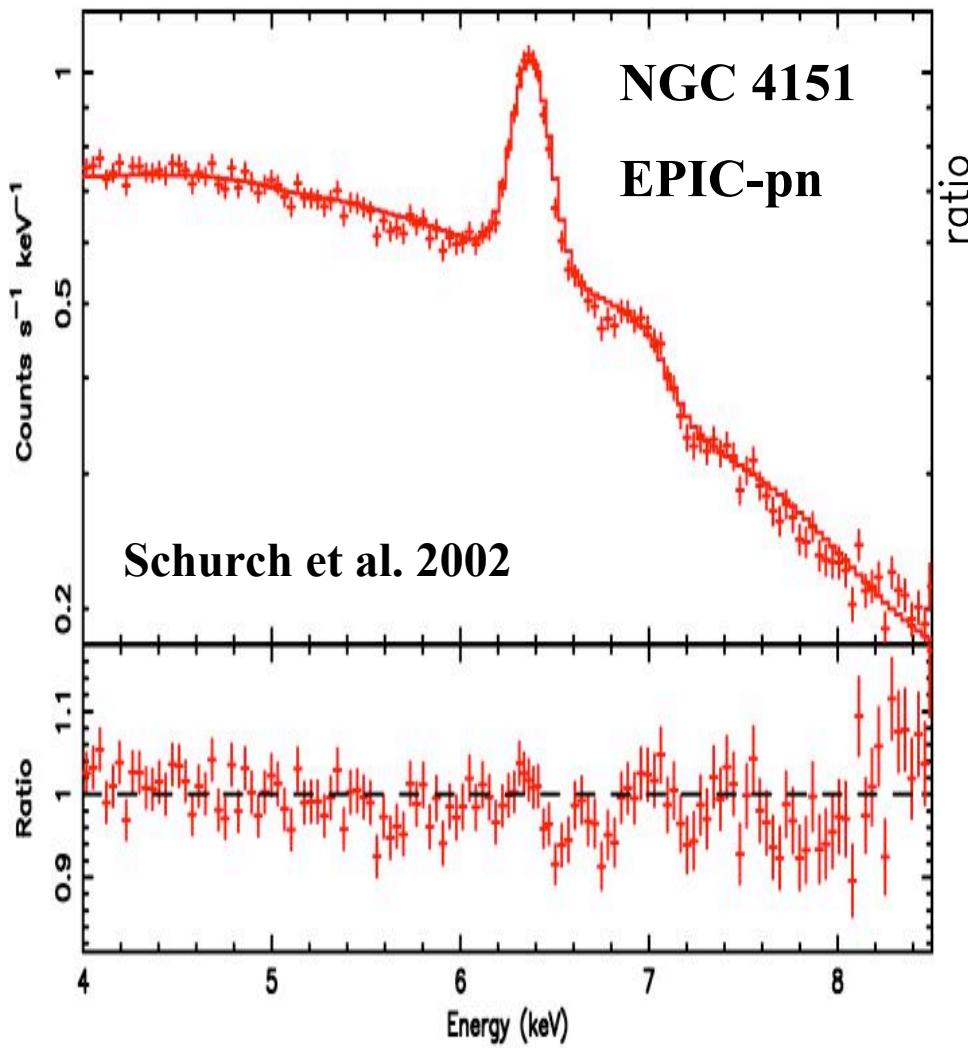
**Broad Iron K $\alpha$  seen by Reflection**

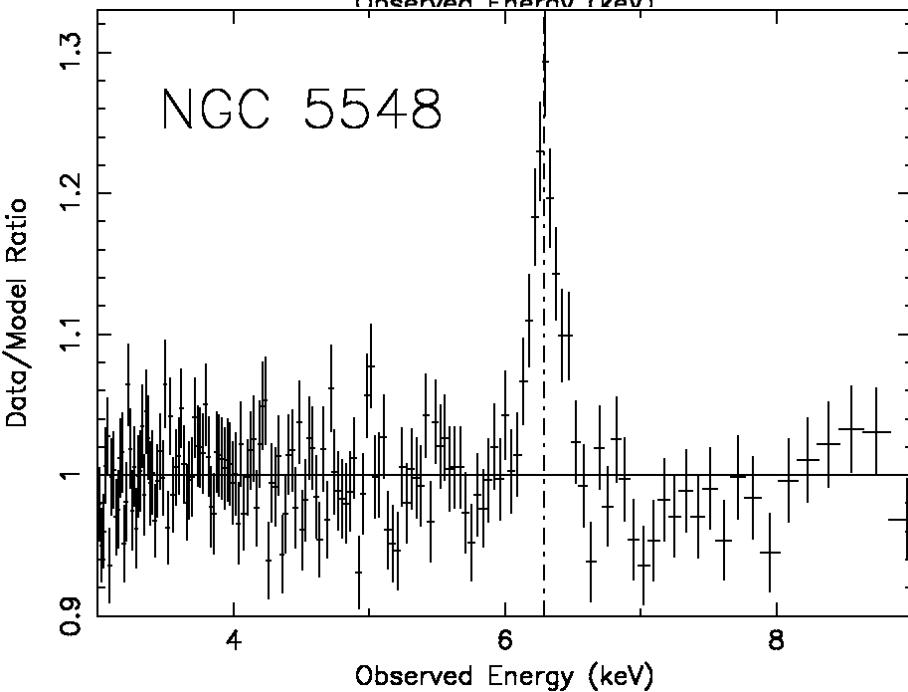
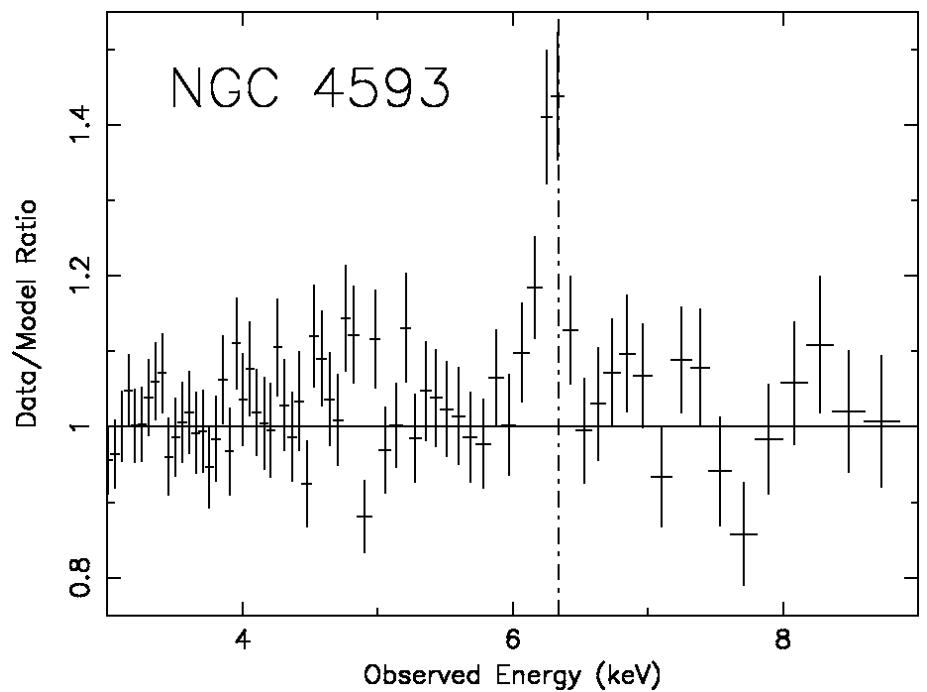
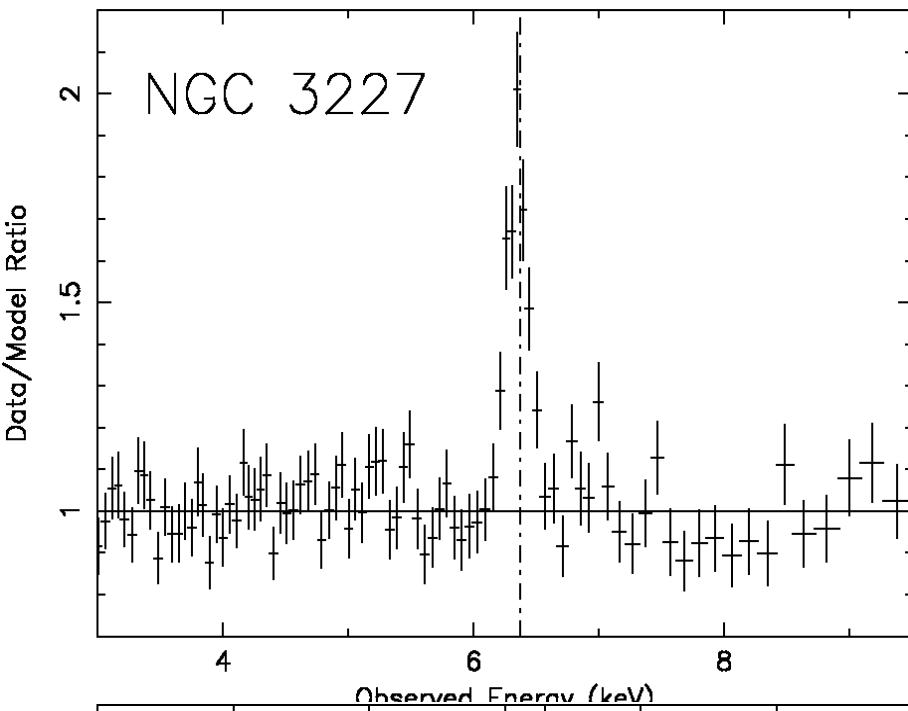
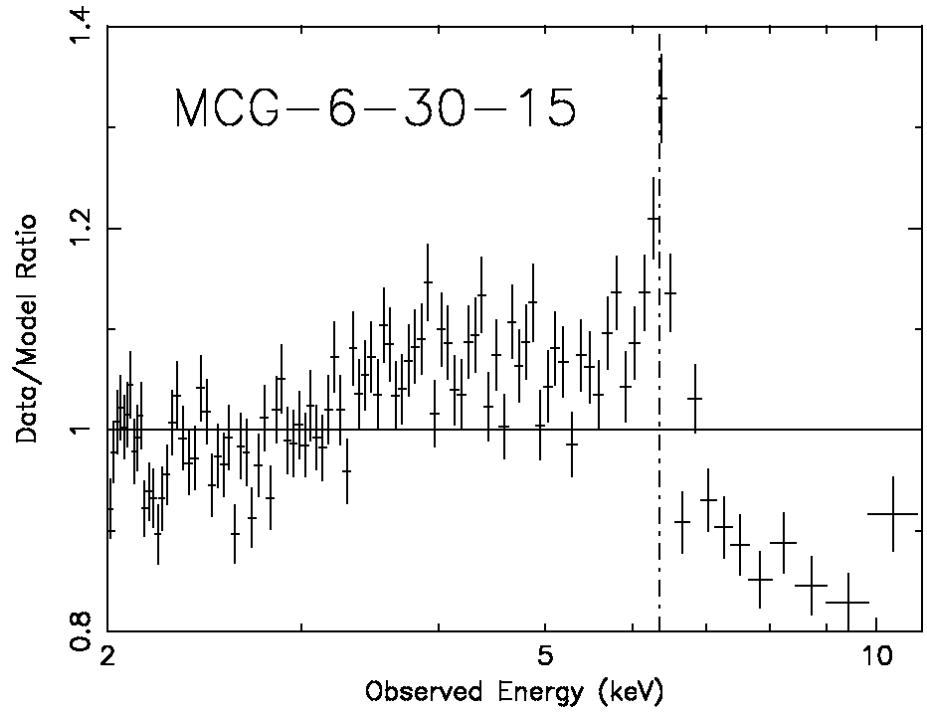
# MCG-6-30-15 – extraction of energy from a spinning black hole?

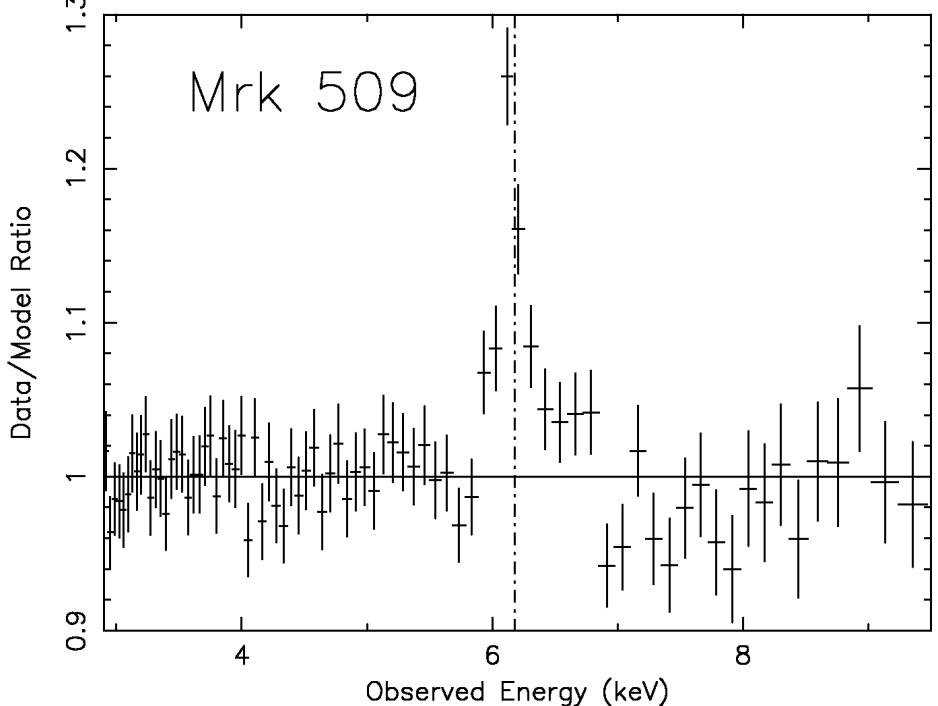
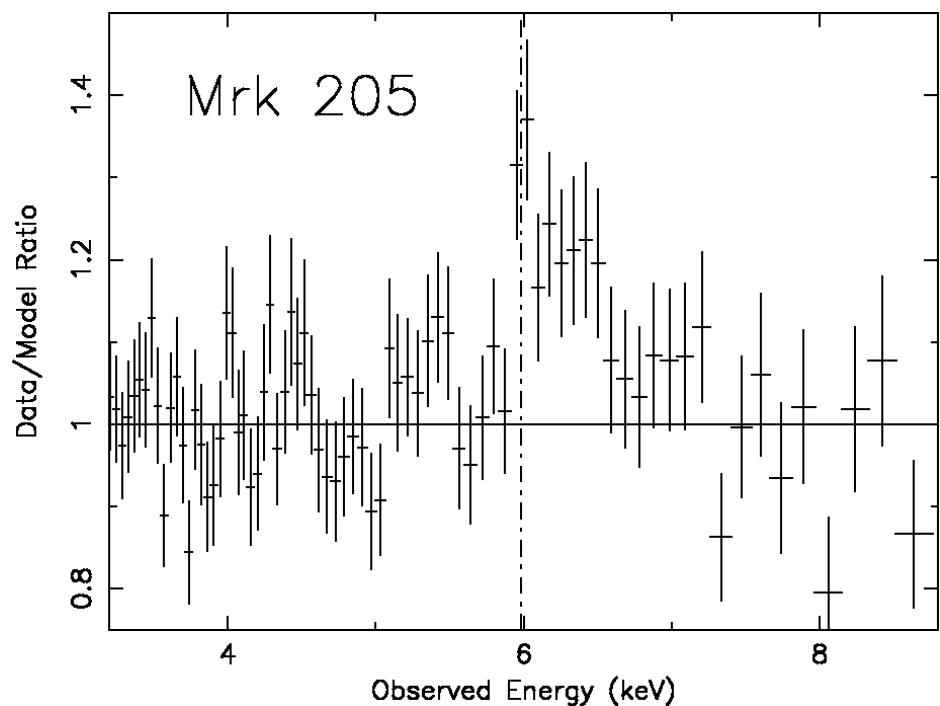
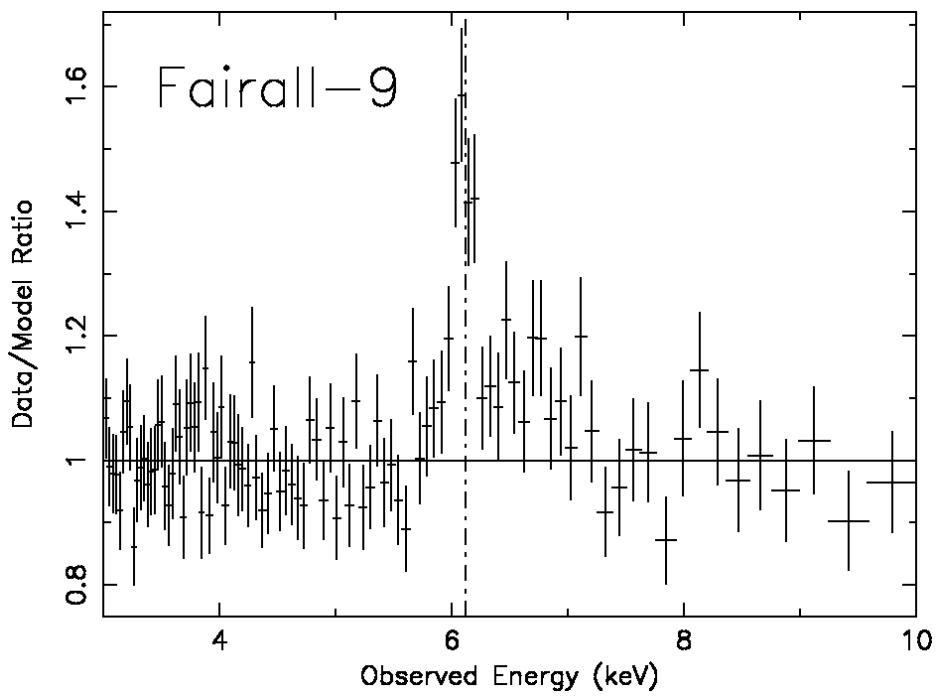
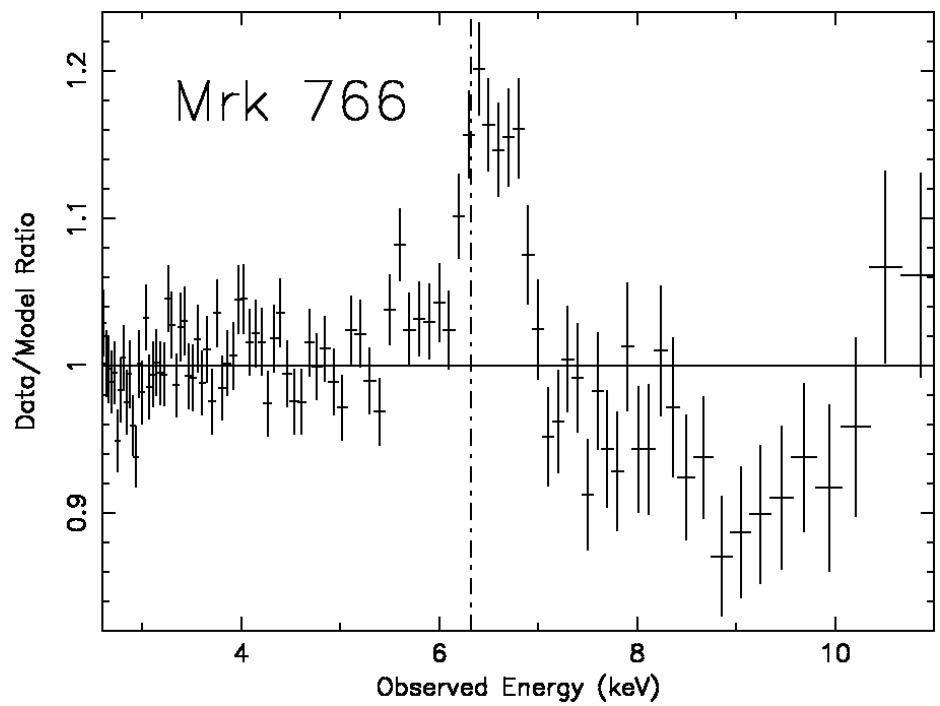


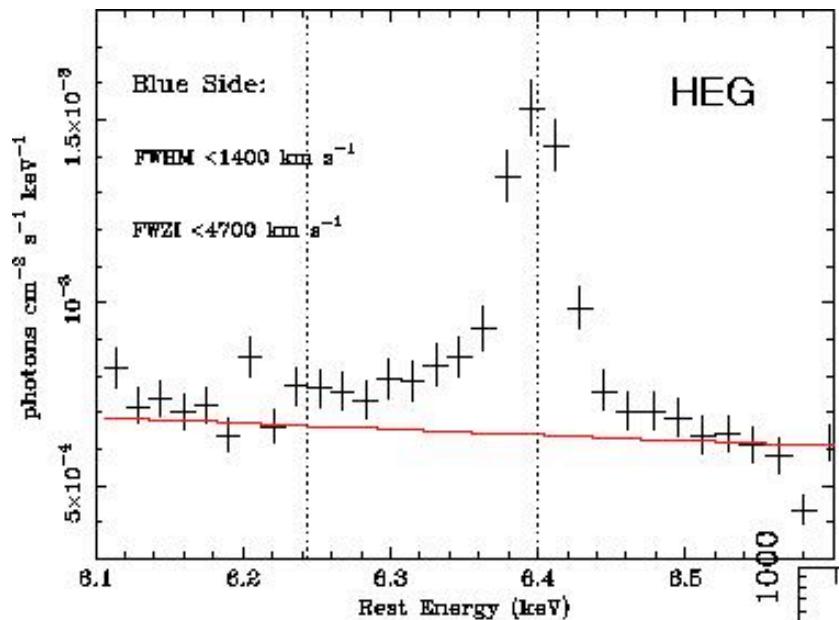
**Spinning black hole?  
(Blandford & Znajek 1977)**

## “Narrow” Iron K lines only in NGC 4151 and NGC 5548









## NGC 3783 – Compton Shoulder

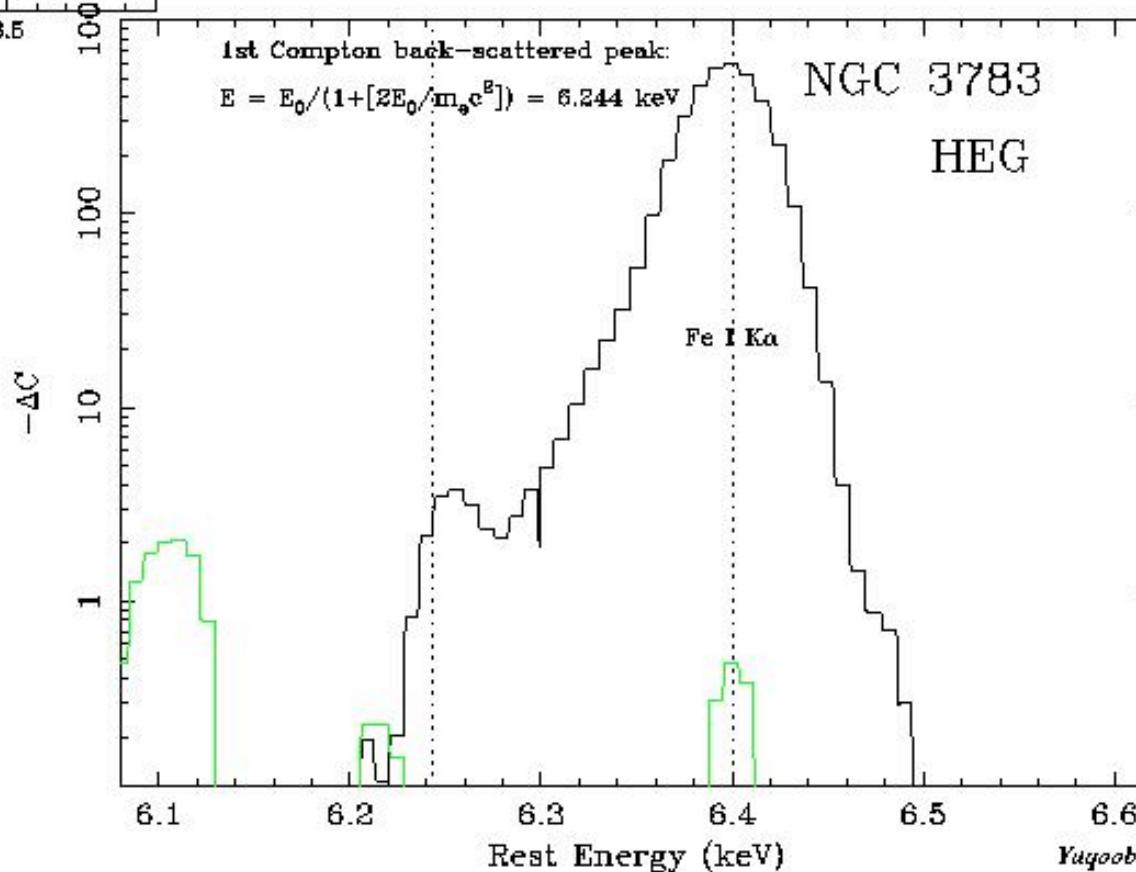
\*850 ks HEG exposure: deduce  $\tau \sim 0.1$

\* Rules out optically-thick disk or torus.

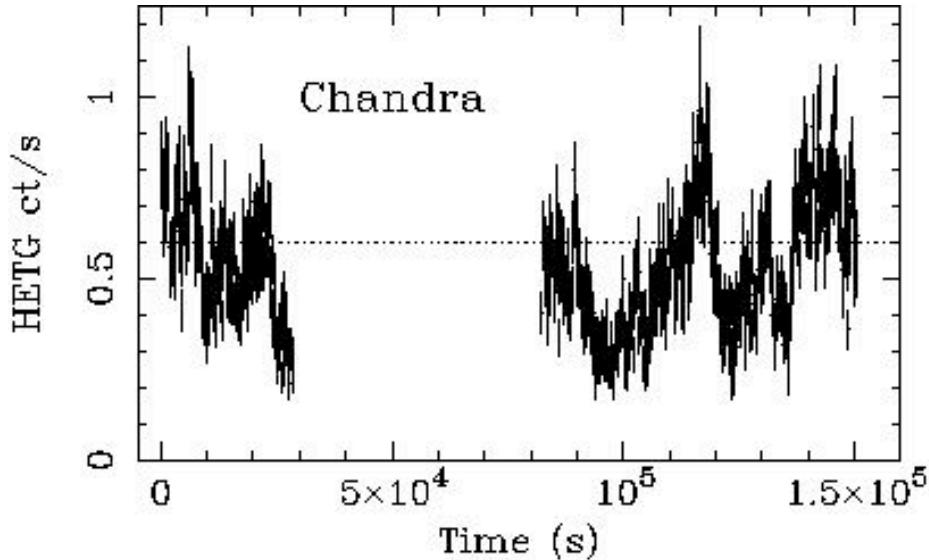
BLR/NLR likely.

Need ~140 ks XRS to do similar science  
for  $F(2-10) = 6.1 \times 10^{-11}$  cgs

$$F(2-10) = 6 \times 10^{-11} \text{ cgs } EW = 70 \text{ eV}$$



*Shoulder peak close to the value for backscattering 6.400 keV photons.  
Deviation is a measure of kT for the medium.*



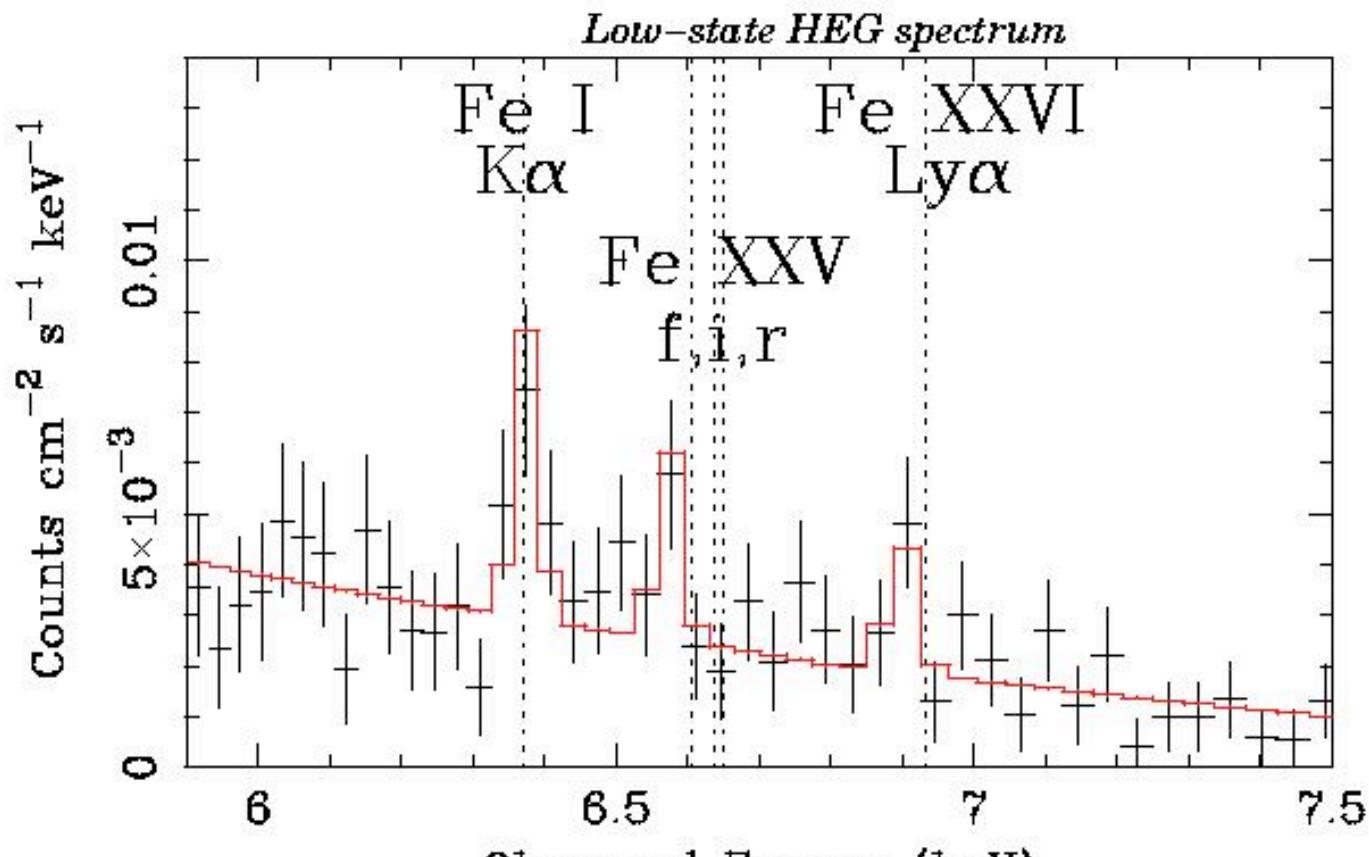
**NGC 7314: Fe XXV & Fe XXVI**  
**Narrow, rapidly variable, unresolved**  
**lines from an accretion disk.**

*He-like & H-like  
lines are redshifted,  
Fe I K line is not.*

*Redshift is  $\sim 1500$  km/s,  
greater than systematic  
& statistical uncertainty.*

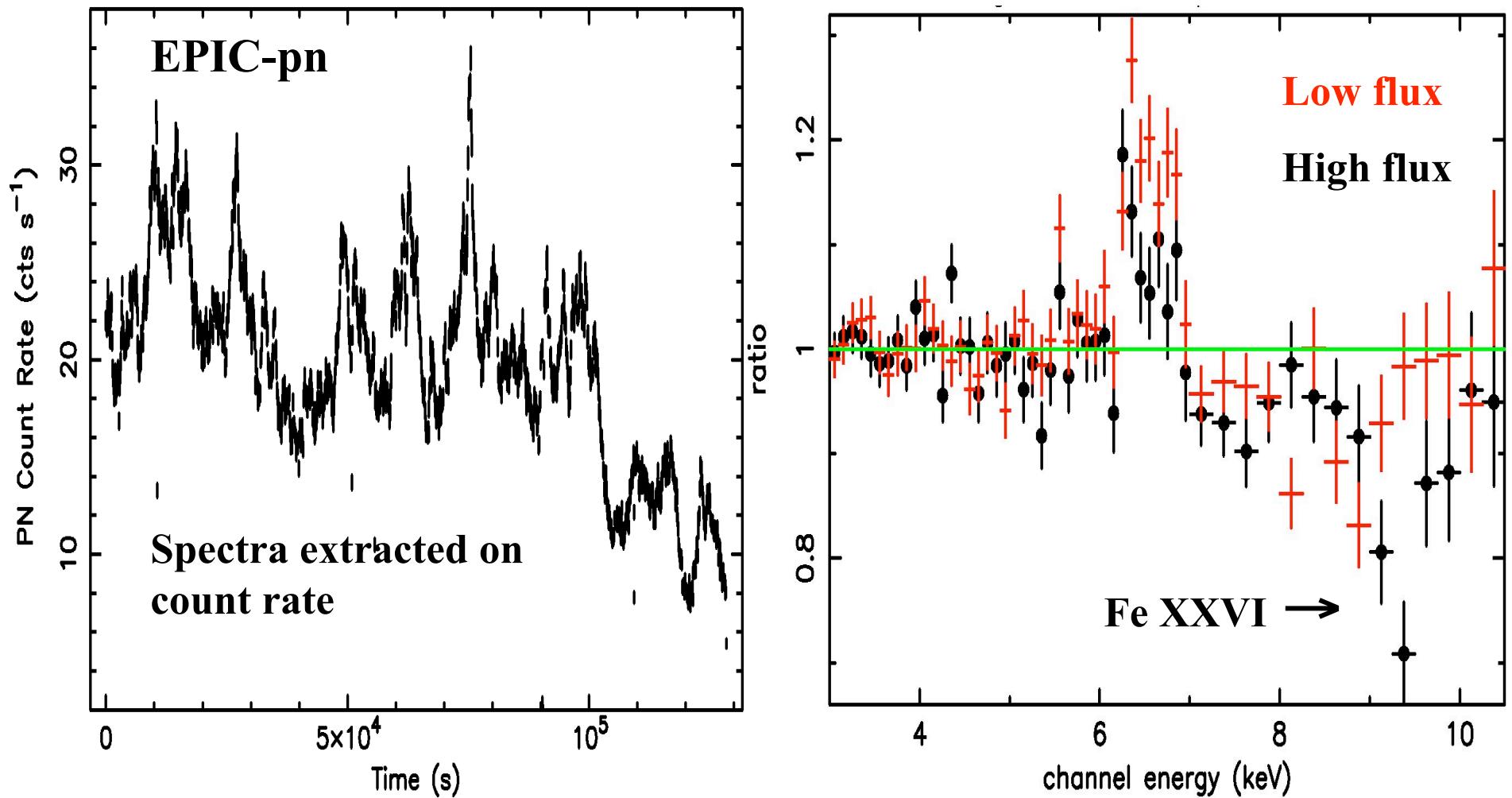
*Is He-like line f,i, or r?  
HEG cannot resolve.*

*Consistent redshift with  
H-like line if forbidden.*



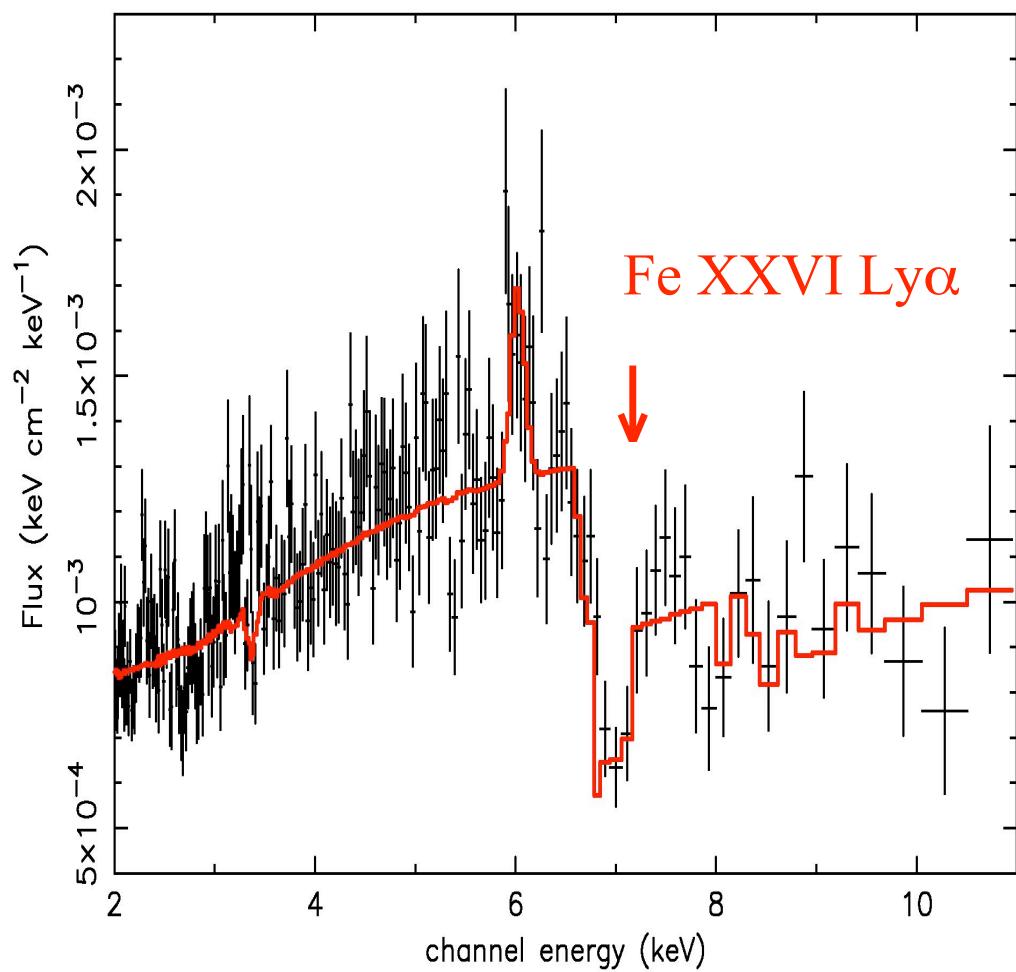
# Highly Ionised Fe K Absorber in Mrk 766 - Evidence for Flare Ejecta?

Fe XXVI absorption only in high flux (“flaring”) state



# A Highly Ionised, Relativistic Outflow in PG 1211+143

PG 1211+143, z=0.081, EPIC-pn



**XMM-Newton data reveal a large, highly ionised outflow**

$\xi \sim 10^{3.4}$  and  $N_H \sim 5 \times 10^{23} \text{ cm}^{-2}$   
outflowing at  $\sim 0.1c$

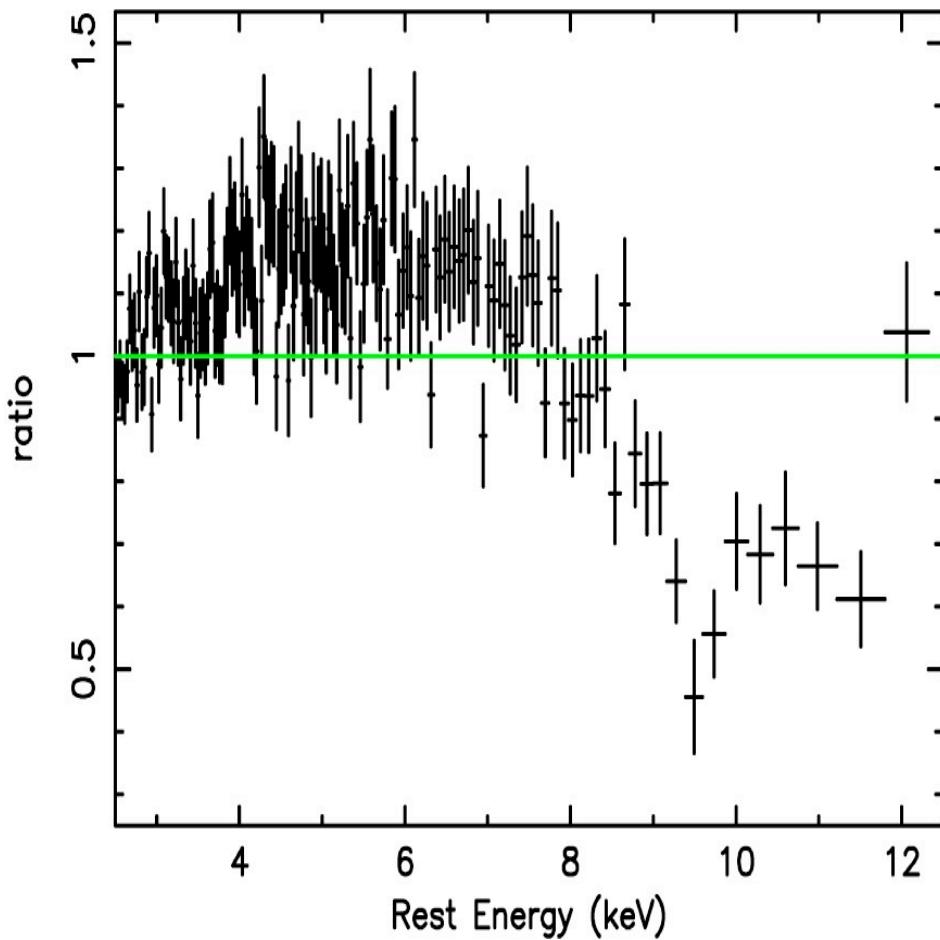
Mass-loss rate  $\sim 0.1 \text{ M}_\odot \text{yr}^{-1}$

K.E.  $\sim 10^{43} \text{ erg s}^{-1}$  (10% L<sub>x</sub>)

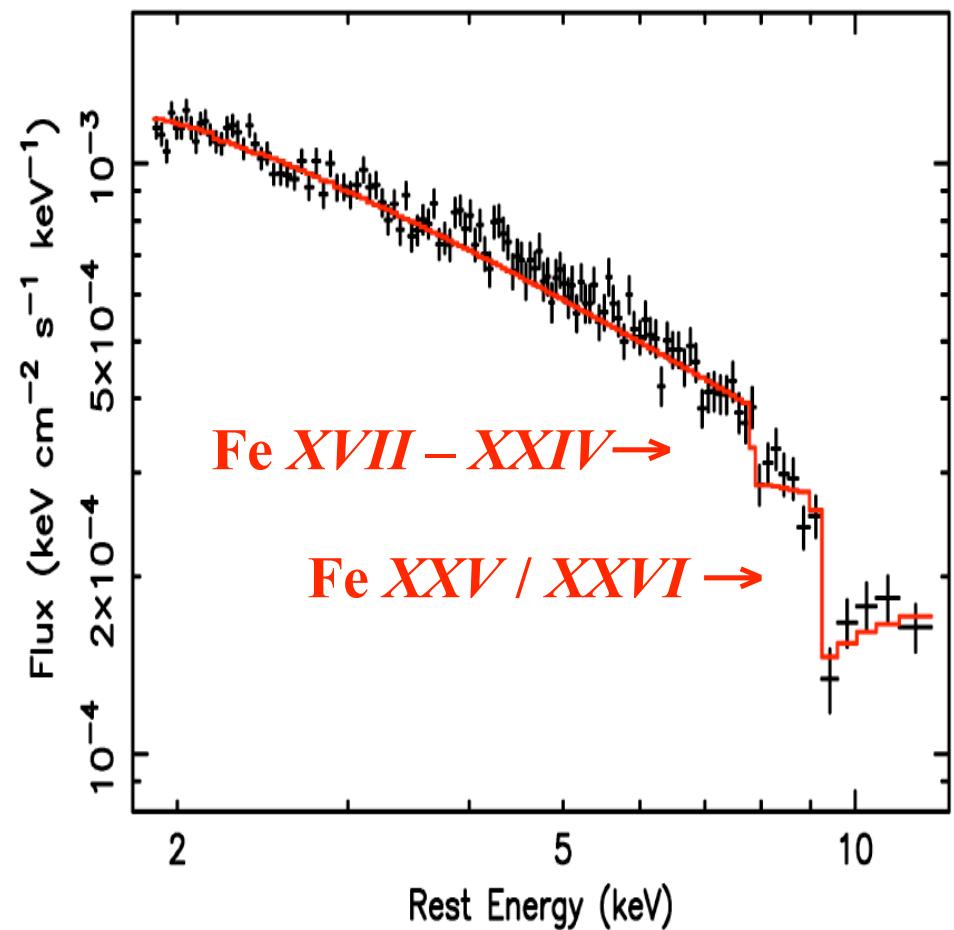
Similar flows in the BAL quasars APM08279+5255 & PG1115+080 (Chartas et al. 2003)

# Iron K-shell absorption in the Quasar PDS 456

Ratio to a Power-law model

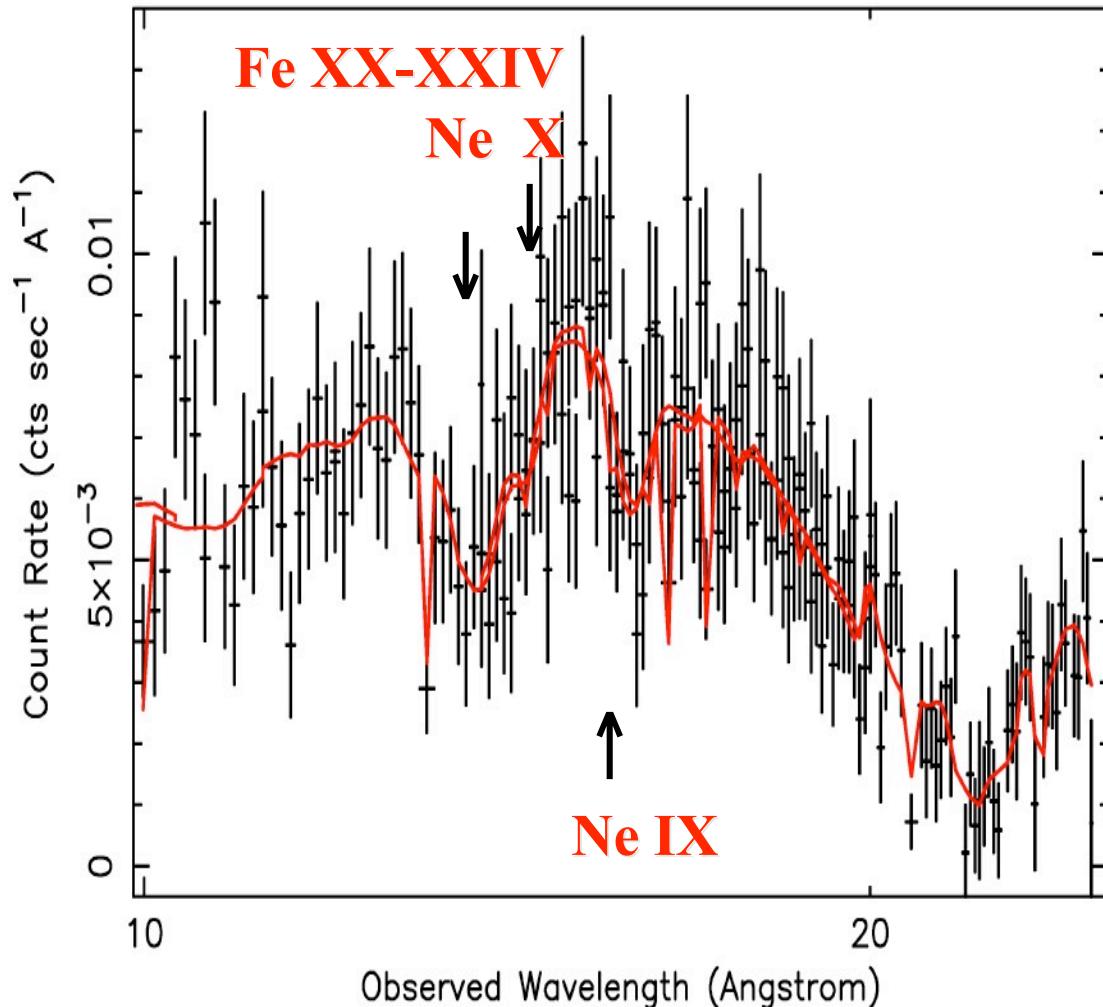


Highly Ionised Iron K edges



# Broad X-ray Absorption Features in PDS 456

XMM-Newton RGS (Reeves et al. 2003)



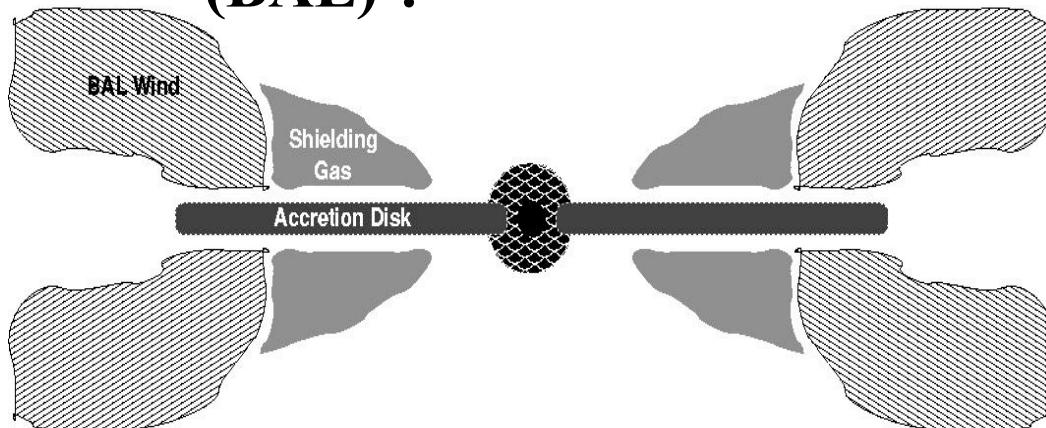
Derive  $\xi \sim 10^3$  and  $N_H \sim 10^{24}$  cm<sup>-2</sup> outflowing at  $\sim 0.15c$  !

If hard X-rays driving outflow, mass-loss rate  $\sim 10$  M<sub>yr</sub><sup>-1</sup>

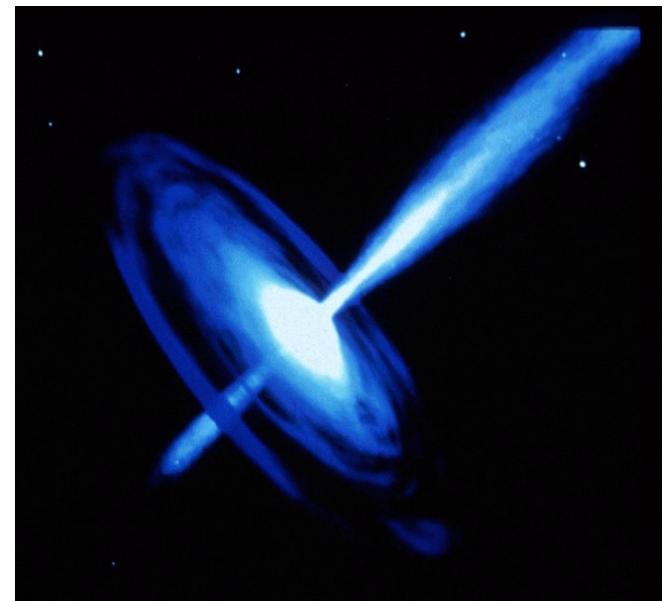
For 10% covering factor, outflow K.E.  $\sim 10^{46}$  erg s<sup>-1</sup> (10% L<sub>bol</sub>)

# Outflow geometry and driving mechanism

Flow along disk plane  
(BAL) ?



Flow along BH axis?

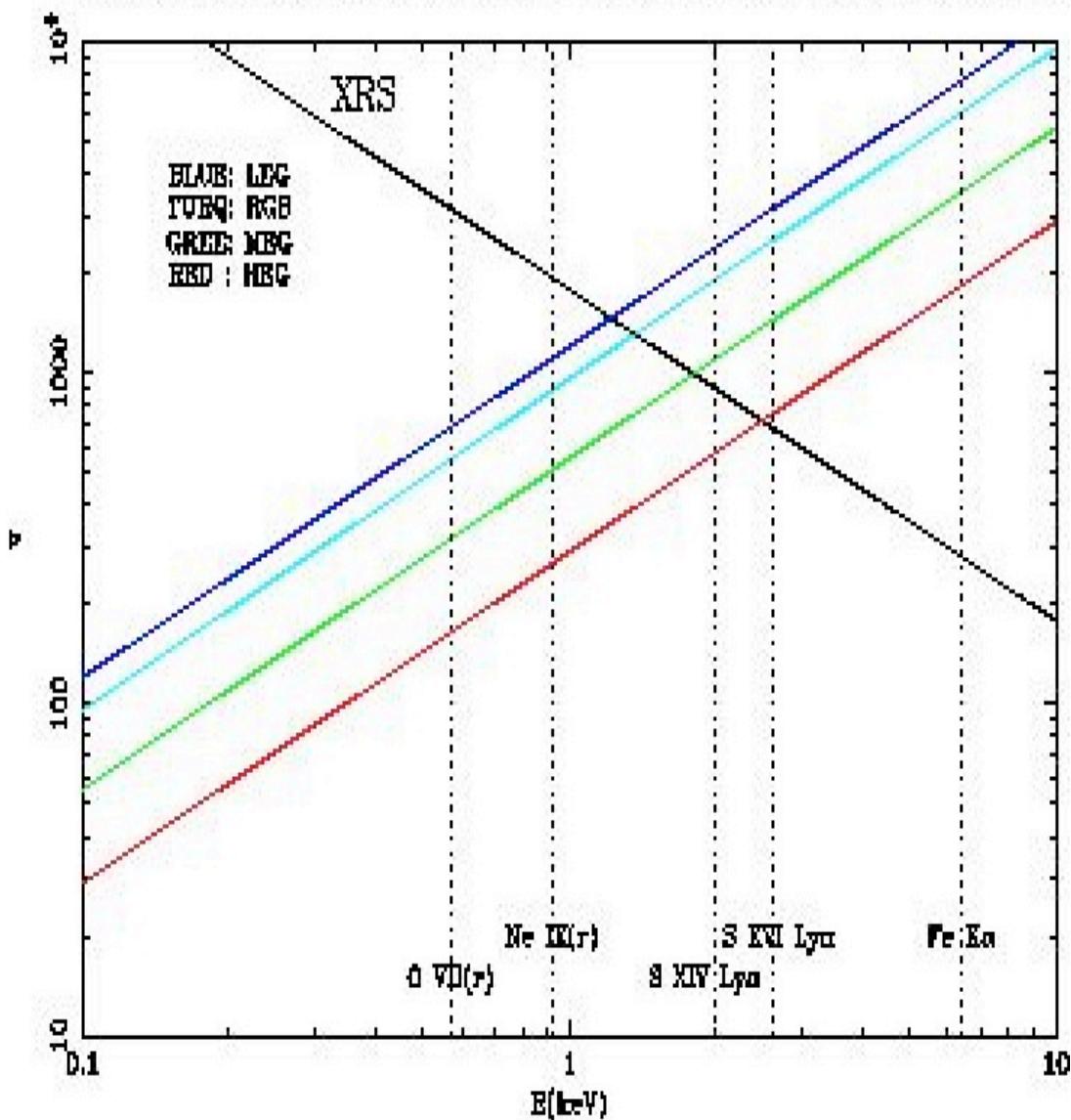


BAL model (left) driven by radiation-pressure. Large, high-ionisation, outflows harder to drive. Need bound-free and/or Compton scattering.

Alternative is magnetic field driving. Significant energy in magnetic field in PDS456.

# LEG RGS MEG HEG XRS

VELOCITY RESOLUTION - Chandra/DMM Gratings (1st order) vs. XRS  
FWHM resolutions- XRS: 6 eV; HEG: 0.012 Å; MEG 0.023 Å; RGS: 0.04 Å; LEG: 0.05 Å



**Highest spatial resolution is needed to resolve iron K band components:- relativistic line, narrow line, ionised components and absorption lines and edges.**

**Calorimeter resolution needed (with  $\Delta v=100-300$  km/s) at 6 keV - Astro-E2 XRS and Constellation-X**

## Conclusions - Observations of the iron K line

- The broad relativistic (extremal Kerr?) appears robust in **MCG -6-30-15**.
- Generally, the simple redshifted broad line scenario (circa ASCA) appears too simplistic.
- Ionised iron K line components are observed in several AGN (**Mrk 205, Mrk 509, NGC 5506, F9, NGC 7314**). Origin in an ionised disc?
- “Narrow” iron K line appears almost ubiquitous in Seyfert 1s (but not QSOs). Origin is unclear (NLR, torus, BLR, outer disc) - needs higher resolution
- Highly ionised outflows detected in several (high accretion rate?) AGN, **PG 1211+143, PDS 456** and **Mrk 766**. Also see Chartas talk.